OPERATING INSTRUCTIONS 874-MD

TYPE 874-MD
SLOTTED-LINE MOTOR DRIVE

. . . . SINCE 1915
manufacturers of
electronic apparatus
for science and industry

GENERAL RADIO COMPANY
CAMBRIDGE 39, MASSACHUSETTS, USA

OPERATING AND MAINTENANCE INSTRUCTIONS

TYPE 874-MD SLOTTED-LINE MOTOR DRIVE

Form 910-A
October, 1955

GENERAL RADIO COMPANY

275 MASSACHUSETTS AVENUE

CAMBRIDGE 39 MASSACHUSETTS

90 West Street
New York 6, New York

8055 13th Street
Silver Spring, Maryland

1150 York Road
Abington, Pennsylvania

920 South Michigan Avenue
Chicago 5, Illinois

1000 North Seward Street
Los Angeles 38, California

REPAIR SERVICES

EAST COAST

General Radio Company
Service Department
275 Massachusetts Avenue
Cambridge 39, Massachusetts

WEST COAST

Western Instrument Company
826 North Victory Boulevard
Burbank, California

CANADA

Bayly Engineering, Ltd.
First Street
Ajax, Ontario

Printed in U.S.A.

SPECIFICATIONS

Length of Sweep	Adjustable from 1 to 45 cm.
Sweep Speed Range	For complete sweep, from one sweep in 20 seconds to better than one per second; for shorter sweeps, approximately five per second.
Maximum Sweep Output Voltage	6 volts.
Power Supply	115 volts, 50 to 60 cycles.
Cables Supplied	Two Type 274-NCO three-foot cables.
Net Weight	16-3/4 lb.

Other Equipment Required

	SQUARE-WAVE MODULATION	SINE-WAVE MODULATION	UNMODULATED SOURCE
Slotted Line	Type 874-LBA Slotted Line	Type 874-LBA Slotted Line	Type 874-LBA Slotted Line
Modulator	Type 1210-B Unit R-C Oscillator	Type 1214-A Unit Oscillator (400 and 1000 cps)	
R-F Oscillator (The comparable signal generator can also be used. The 900-2000-Mc signal generator requires external modulation.)	Type 1218-A Unit U-H-F Oscillator (900 to 2000 Mc)	Type 1208-B (65 to 500 Mc), 1209-B (250 to 920 Mc), or 1218-A* (900 to 2000 Mc)	Type 1208-B (65 to 500 Mc), 1209-B (250 to 920 Mc), and 1218-A (900 to 2000 Mc)
Pad	Type 874-GJ 10-db Pad	Type 874-GJ 10-db Pad	Type 874-GJ 10-db Pad
Oscilloscope	At least 10 mv/in. sensitivity (dc)	About 0.1 v/in. sensitivity (dc)	At least 10 mv/in. sensitivity (dc)
Resistor	Approx 30 kilohms	Approx 30 kilohms	Approx 30 kilohms
Amplifier		Type 1231-B Amplifier and Null Detector	

*square-wave modulated with Type 1210-B Unit R-C Oscillator

U.S. Patent No. 2,548,457

Type 874-GJ now Type 874-G10

TABLE OF CONTENTS

Page

Section 1. THE MOTOR DRIVE UNIT 1

1.1 Introduction 1
1.2 Principles of Operation 3
1.3 Installation 5
1.4 Motor Speed Characteristics 7
1.5 Operating Procedure 8

Section 2. SOURCE-AND-DETECTOR SYSTEM 9

2.1 General 9
2.2 Oscilloscope Requirements 9
2.3 Square-Wave Modulation 10
2.4 Sine-Wave Modulation 12
2.5 Unmodulated Source 14

Section 3. PRESENTATION 15

3.1 Setup Procedure 15
3.2 Measurement Procedure 16
3.3 Expression for the Standing-Wave Pattern 17
3.4 Detector Characteristics 18
3.5 Display Difficulties 19

Section 4. SERVICE AND MAINTENANCE 21

4.1 General 21
4.2 Factory Service 21
4.3 Lubrication 21
4.4 Microswitch Replacement 21

Section 5. PARTS LIST 24

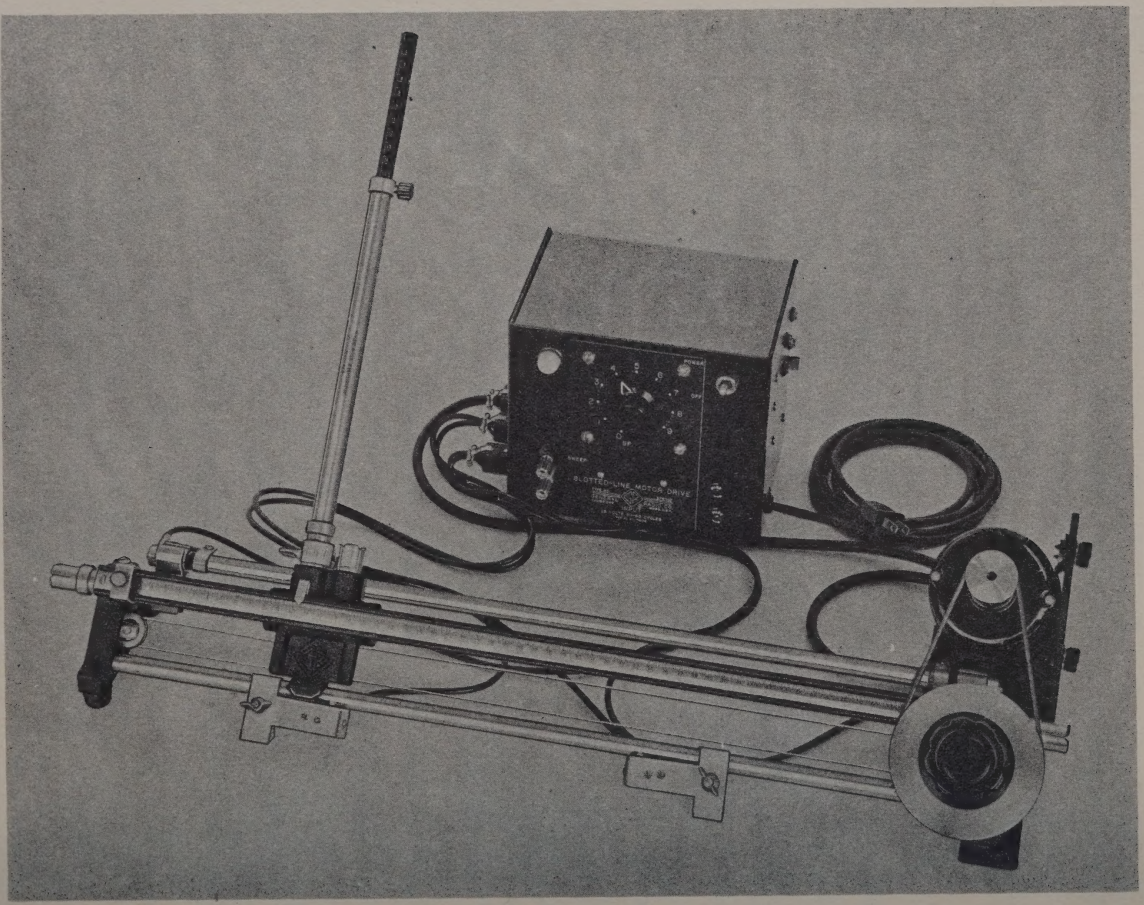

Figure 1. Type 874-MD Slotted-Line Motor Drive Assembled with Type 874-LBA Slotted Line

FOREWORD

This instruction book describes the operation of the Type 874-MD Motor Drive, used with the Type 874-LBA Slotted Line, and the visual presentation of the standing-wave pattern made possible by this assembly. Any theoretical considerations or measurement techniques described herein are provided in order that an accurate display may be presented and to aid in the interpretation of this display.

The general theory of the slotted line and the techniques for measurements at fixed points along the line are discussed in the instruction book for the Type 874-LBA Slotted Line, which will be used as a reference in the following sections.

Section 1

THE MOTOR DRIVE UNIT

1.1 INTRODUCTION.

1.1.1 PURPOSE. The Type 874-MD Slotted-Line Motor Drive (Figure 1) is used to sweep the Type 874-LBA Slotted-Line probe carriage mechanically in order to give an indication of the voltage standing-wave pattern along the line. This arrangement eliminates the necessity of point-by-point measurement in many applications and provides a continuous indication as the pattern is changed.

The combination of Type 874-MD Motor Drive and Type 874-LBA Slotted Line may be used at slow sweep speeds with a VSWR meter, or may be used at higher speeds to give a visual presentation of the standing-wave pattern on a cathode-ray oscilloscope. With the visual display, both the VSWR and the position of voltage minima may be read directly, so that the impedance terminating the line can be determined.

1.1.2 DESCRIPTION. The Motor Drive Unit includes a continuously variable Variac® speed control, which provides a wide range of sweep speeds. The sweep distance, determined by the positions of two reversing switches, is also variable. The SWEEP terminals provide a horizontal deflection voltage, proportional to the position of the probe carriage, for the oscilloscope.

The components of the Type 874-MD Motor Drive are shown assembled in Figure 1 and separately in Figure 2. The assembly comprises:

a. a 1/50-hp d-c motor with mounting bracket and pulley,
b. a Variac speed control unit,

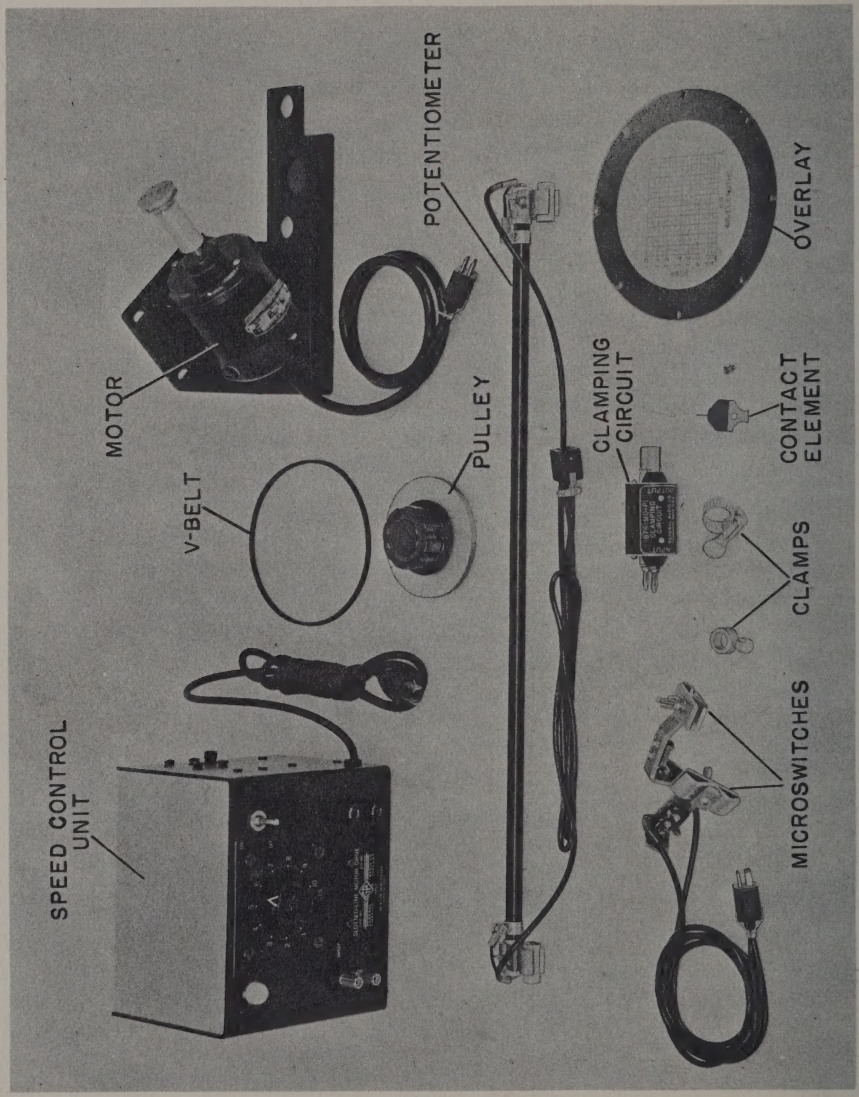

Figure 2. Components of the Type 874-MD Slotted-Line Motor Drive

c. a pulley for the slotted-line shaft,
d. two microswitches mounted on brackets, and one spare microswitch,
e. a V-belt,
f. a linear potentiometer wound on a rod,
g. a potentiometer contact element, and one spare element,
h. two clamps: one to hold the tuning stub in place and one to keep the stub extension constant,
i. a clamping circuit (Type 874-MD-P1), used to present a base line on the oscilloscope when an a-c amplifier is used in the detector circuit (refer to paragraph 2.4.3),
j. a transparent overlay for a five-inch oscilloscope, calibrated to indicate VSWR directly.

1.2 PRINCIPLES OF OPERATION.

1.2.1 CIRCUIT.

1.2.1.1 General. The circuitry of the Motor Drive Unit is simple and straightforward, and may be divided into three electrically independent circuits: the potentiometer circuit (horizontal sweep circuit), the switching circuit, and the motor speed control circuit.

1.2.1.2 Potentiometer Circuit. The potentiometer circuit (Figure 3) is simply a d-c voltage source connected across a potentiometer. The sliding contact is grounded to eliminate the need for an additional connecting lead to the moving carriage.

1.2.1.3 Switching Circuit. The switching circuit is shown in Figure 4. Each microswitch, when depressed by the probe carriage, momentarily closes the circuit of one of the relay coils. Because of the latching mechanism, the other relay will also switch, and only momentary coil current is necessary. The latching mechanism is shown in Figure 19.

1.2.1.4 Motor Speed Control Circuit. The motor speed control circuit is shown in Figure 5. The field circuit is a simple bridge rectifier. The

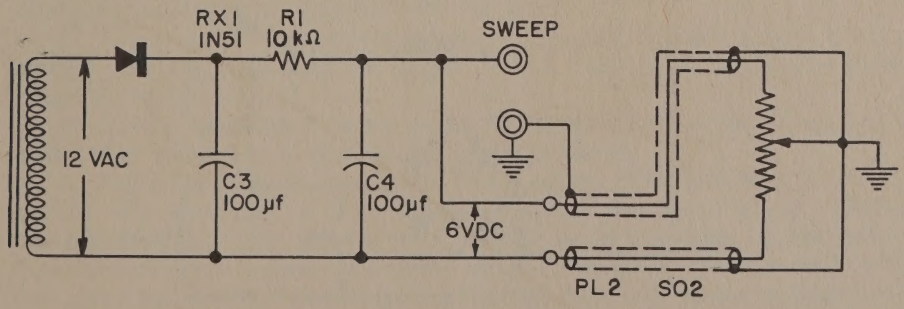

Figure 3. Potentiometer Sweep Circuit.

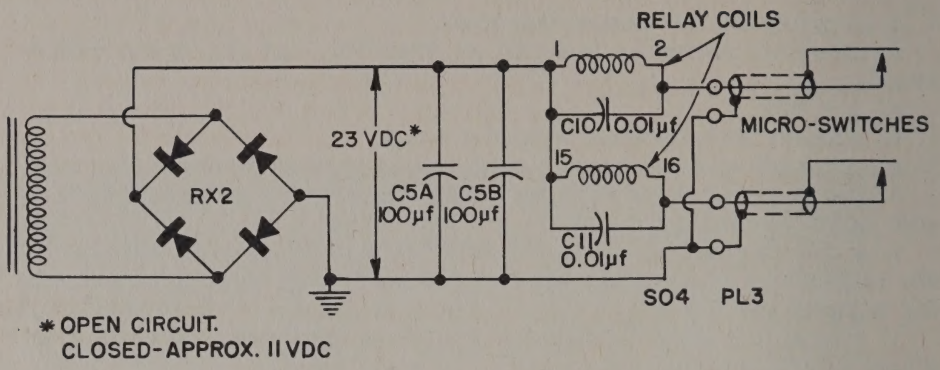

Figure 4. Switching Circuit.

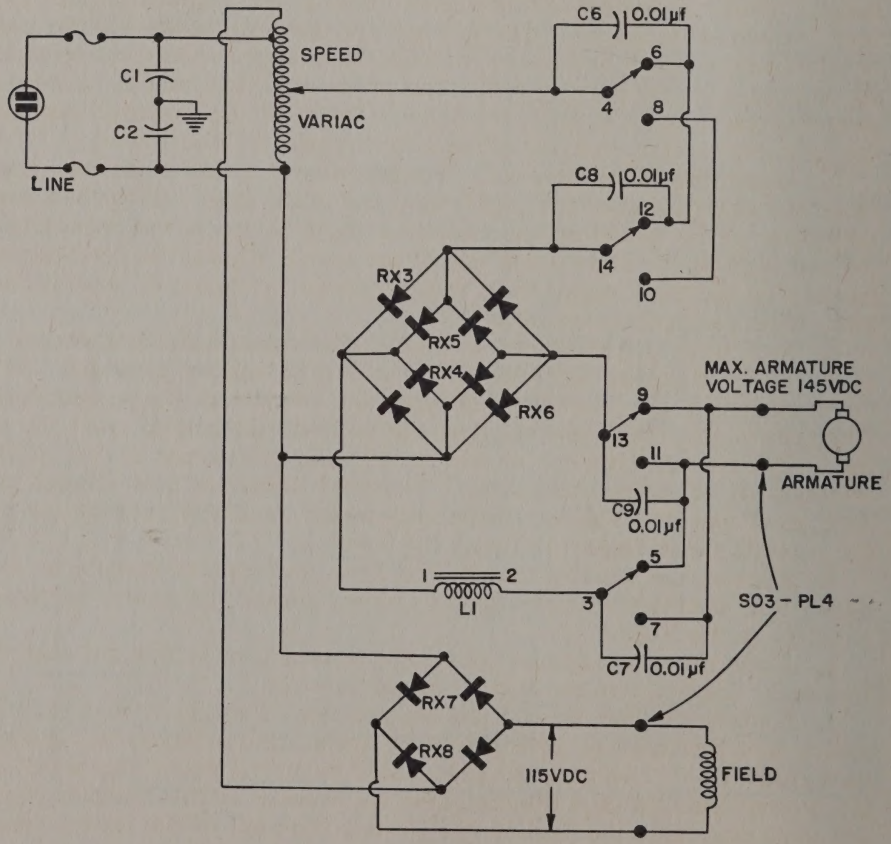

Figure 5. Motor Speed Control Circuit.

armature circuit is more complex, since voltage is varied by the Variac to vary motor speed, while the direction of current flow is reversed by the relays. Each relay has two double-throw switches; the latching mechanism causes all switches to be thrown simultaneously. In each relay, one switch is used in a simple reversing circuit, and the other is used to open the a-c supply during the switching. The inductor limits the surge current and the capacitors absorb the inductive voltage pulse during the switching.

1.3 INSTALLATION.

1.3.1 GENERAL. Although the assembly procedure is simple, the instructions given below are important to the proper operation of the Motor Drive. A detailed diagram of the setup is given in Figure 6.

1.3.2 PROCEDURE.

a. Attach the microswitches. Leads to the microswitches are color-coded. Place the switch with the green lead at the right-hand side of the line. Attach switches as shown in Figure 6. Rest the bottom of the switch bracket on the bench and press the opposite end of the bracket up against the Slotted-Line supporting rod. The probe carriage should depress the switch contacts and yet slide freely over them. If the carriage depresses the contacts too far, the life of the switches will be shortened.

b. Mount the potentiometer. Potentiometer leads are color-coded. Place the green lead at the right-hand end of the line. (If the horizontal amplifier of the oscilloscope reverses the polarity of the signal, place the red lead at the right-hand end of the line.) Clamp the potentiometer loosely on the rear supporting rod as shown in Figure 6, and rotate it away from the probe carriage.

c. Attach the potentiometer contact. The contact element screws onto the probe carriage with the screw and lock washer provided. Mount the contact with the contact tip curving up, away from the potentiometer. When the contact is in place, rotate the potentiometer up to meet the contact. The contact element should travel near the center of the cleaned-off segment of the potentiometer. Pressure should be just enough to insure good contact. Tighten the potentiometer brackets, making sure that the potentiometer is parallel with the line.

d. Remove the knob of the Slotted Line and replace it with the knob-pulley unit supplied with the Motor Drive. Mount the pulley as close as possible to the line.

e. Place the motor bracket under the Slotted Line so that the feet of the line enter the holes in the bottom of the bracket.

f. Place the V-belt around the two pulleys. Two grooves in the motor pulley are provided to give different speed characteristics. (Refer to paragraph 1.4.) The groove used should be in the plane of the pulley on the Slotted Line. Adjust the motor on its bracket so that the belt is tight, but does not raise the feet of the Slotted Line out of the motor bracket holes.

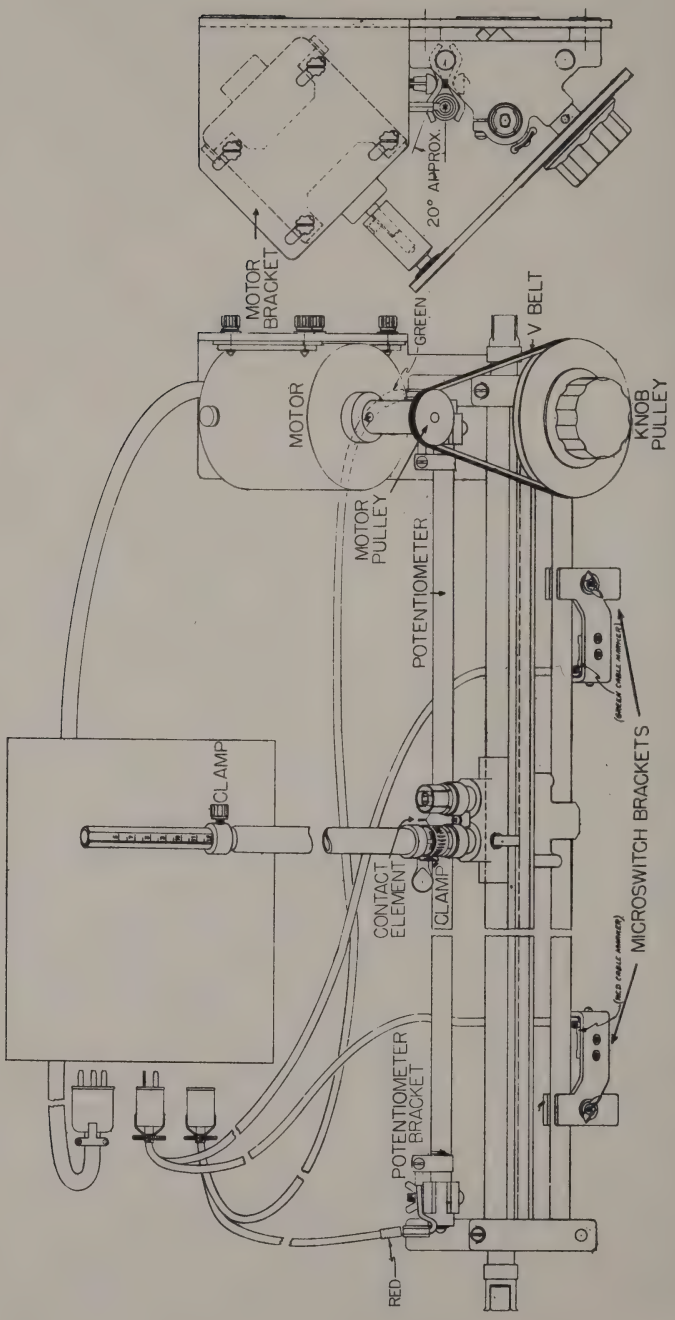

Figure 6. Assembly Diagram.

g. Remove the tuning stub (Type 874-D20) and place the larger clamp over the connector. (See Figure 6.) Replace the stub and tighten the clamp firmly.

h. Slide the smaller clamp over the end of the stub. (Tighten this clamp after tuning the stub to prevent the stub from sliding in due to vibration.)

i. Connect the potentiometer, microswitch, and motor leads to the speed control unit by means of the various sockets on the side of that unit. It is impossible to connect the leads to the wrong sockets.

1.4 MOTOR SPEED CHARACTERISTICS. The combination of the Variac motor speed control and the choice of two motor pulleys provide a wide range of sweep speeds. The smaller pulley, which should be used at slow speeds, permits smooth operation for a time duration up to more than 40 seconds for one cycle (forward and reverse) for a full sweep distance of 45 centimeters. With the larger pulley speed can be increased to several cycles per second.

There are some limitations on use at higher speeds. Vibration may cause a noisy display (refer to paragraph 3.5), and the overshoot of the probe carriage may cause the carriage to strike the microswitch brackets.

The temperature rise of the motor is also a limiting factor, since the motor life will be shortened if the motor becomes too hot. This consideration is especially critical at short sweep distances where the motor is reversed often. Figure 7 is a plot of the maximum speed control setting vs distance of travel recommended for continuous operation at room temperatures. Much faster operation is possible for short periods with-

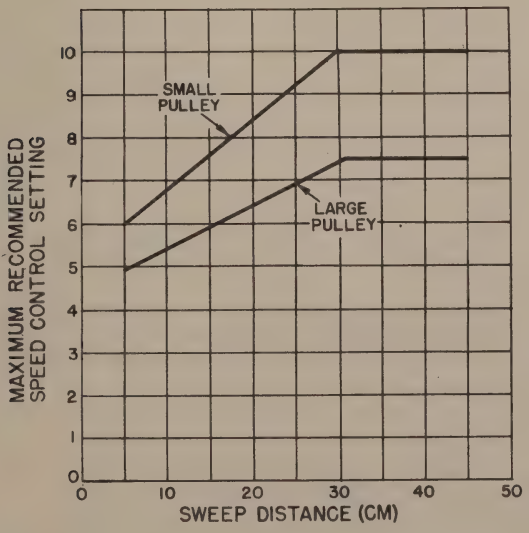

Figure 7. Maximum Recommended Speed Control Setting vs Distance of Travel.

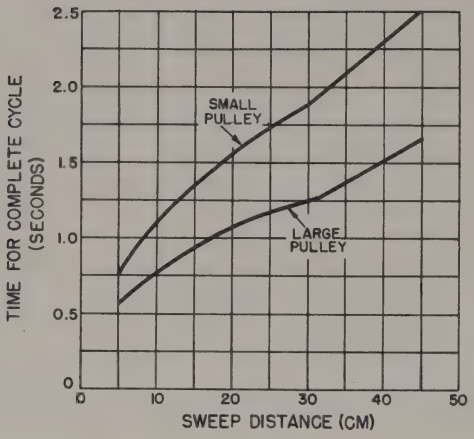

Figure 8. Time for Complete Cycle vs Distance of Travel at Recommended Maximum Speed Control Setting.

out serious overheating. Figure 8 gives the time for a complete cycle vs distance when operated at the recommended maximum speed for a typical unit. In these two plots the distance is that set by the microswitch positioning. The actual distance will be slightly greater due to overshoot.

1.5 OPERATING PROCEDURE.

1.5.1 GENERAL. The procedure given below is for operation of the Motor Drive Unit itself. In order to make measurements or to present a visual display, a source-and-detector system is, of course, necessary. (Refer to Section 2.) The measurement procedure is given in Section 3.

1.5.2 PROCEDURE.

a. Assemble the unit as described in paragraph 1.3.2.
b. Set the speed control knob to zero.
c. Position the microswitches as desired.
d. Position the probe carriage between the two microswitches manually by means of the knob on the Slotted Line.
e. Plug in the line cord to a 115-volt, 50- to 60-cycle power line.
f. Turn on the motor control unit.
g. Increase the speed slowly to check the operation of the assembly. If the probe carriage should pass one of the microswitches due to improper mounting of the switch, manually depress the switch to reverse the motor, and adjust the mounting properly.

NOTE

For smooth, long-life operation it is essential that the Slotted Line be kept well lubricated. (Refer to paragraph 4.3.)

Section 2
SOURCE-AND-DETECTOR SYSTEM

2.1 GENERAL. In order to make measurements on the Slotted Line, a source-and-detector system is necessary. The Instruction Book for the Type 874-LBA Slotted Line describes various systems that can be used with a meter display. The Motor Drive, used at low speeds, is useful with a meter display to provide uniform carriage speed and to free the hands of the operator. The signal may be unmodulated if a sensitive microammeter is used, or modulated (sine or square wave) if an amplifier and meter are used. (General Radio Type 1231-B Amplifier is recommended.)

For an oscilloscope display it is desirable to modify the source-and-detector system so that a base line is also presented, although in instances this is not necessary. The equipment used depends upon the type of presentation desired and on the instruments available for use at the desired frequency.

Three types of display are discussed in the following paragraphs. These are displays using square-wave modulation, sine-wave modulation, and an unmodulated signal.

2.2 OSCILLOSCOPE REQUIREMENTS.

2.2.1 In order to present a clear and accurate visual display it is desirable that the oscilloscope have the following characteristics:

a. high vertical d-c gain (at least 10 mv/in. sensitivity with square-wave modulation or no modulation; approximately 100 mv/in. with sine-wave modulation),
b. d-c horizontal gain (0.1 v/in. sensitivity),
c. a long-persistence screen (P-7 phosphor) with a five-inch tube,
d. a high accelerating potential
e. good linearity,
f. low drift,
g. bandwidth of approximately 100 kc for square-wave modulation.

2.2.2 Some oscilloscopes that give satisfactory results are the Dumont Types 304-H and 324 and the Waterman Type S-14A (three-inch tube requires special overlay).

2.2.3 A d-c preamplifier can be used only if it meets the following requirements:

a. The input and output must have a common ground, since the oscilloscope ground is connected to the Slotted-Line ground through the horizontal sweep circuit.

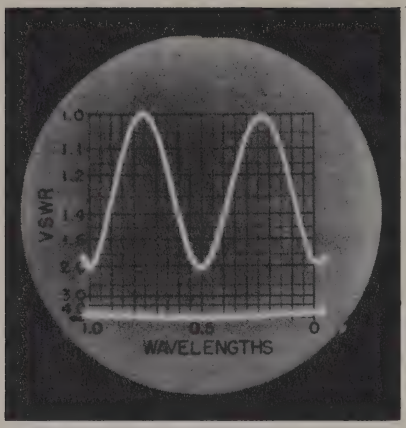

Figure 9. Standing-Wave Pattern Obtained with Square-Wave Modulation.

b. The output (for zero d-c input) may be slightly above or below ground potential only if this voltage is small enough to be corrected by the vertical centering control.

c. The circuit should not present any bias voltage to the crystal detector.

2.3 SQUARE-WAVE MODULATION.

2.3.1 GENERAL. One-hundred-percent square-wave modulation is recommended when such a source is available. The display (Figure 9) is clear, and incidental frequency modulation is negligible. High d-c gain in the oscilloscope is important with this type of modulation. Square-wave modulation may also be used with an a-c amplifier and a less sensitive oscilloscope if the Type 874-MD-P1 Clamping Circuit is used. The set-up and operation are the same as for sine-wave modulation (refer to paragraph 2.4).

2.3.2 INSTRUMENTS REQUIRED. The source-and-detector system is shown in Figure 10. Recommended components are as follows:

Square-Wave Generator. Type 1210-B Unit R-C Oscillator gives square-wave output.

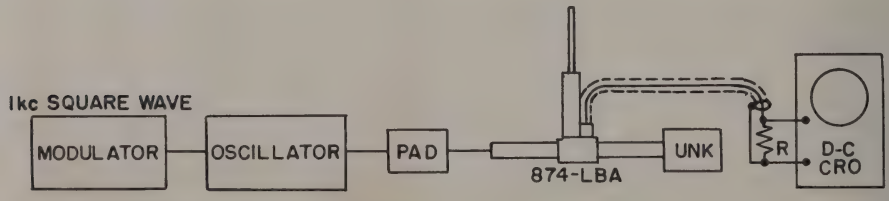

Figure 10. Source-and-Detector System for Square-Wave Modulation.

R-F Oscillator. Type 1218-A Unit U-H-F Oscillator can be used in the frequency range of 900 to 2000 Mc.

Type 1021-AW Standard-Signal Generator (900 to 2000 Mc) (external modulation)

NOTE

The Types 1208-B and 1209-B Unit Oscillators for lower frequencies cannot be square-wave modulated by the Type 1210-B Unit R-C Oscillator.

Pad. Type 874-GJ 10-db Pad recommended to isolate the oscillator and produce a 50-ohm source impedance. It also helps reduce the input signal and yet keep the Type 1218-A Unit Oscillator output adjustment in the middle of its range.

Resistor. Approximately 30 kilohms (refer to paragraph 3.4).

Oscilloscope. At least 10 mv/in. sensitivity (dc).

2.3.3 OPERATION. The general procedure for an oscilloscopic display is given in paragraphs 3.1 and 3.2. There are, however, some considerations that are peculiar to this type of modulation. The most important factor in obtaining good square-law response (refer to paragraph 3.4) is high d-c gain in the oscilloscope. If the oscilloscope has an internal y-axis sensitivity adjustment, set this for maximum gain, and adjust the output of the r-f oscillator to the desired level.

Make sure that the r-f oscillator is completely modulated, that is, turned off for half the a-c cycle. If the oscillator is not completely modulated, the base line will not represent ground potential and will become sinusoidal.

If the bandwidth of the oscilloscope is too small, the audio-frequency envelope will have a long rise time, resulting in illumination between the base line and the top of the square wave.

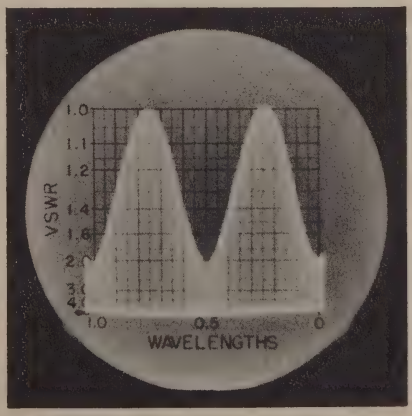

Figure 11. Standing-Wave Pattern Obtained with Sine-Wave Modulation.

2.4 SINE-WAVE MODULATION.

2.4.1 GENERAL. An advantage of sine-wave modulation is that a-c gain can be used, requiring less d-c gain in the oscilloscope and yet maintaining the low r-f level necessary for good square-law detector response. A clamping circuit is needed to obtain a base line. The display is shown in Figure 11. Note that the area between the two lines is illuminated since the r-f level changes sinusoidally.

Sine-wave modulation is recommended when square-wave modulated sources are unavailable.

2.4.2 INSTRUMENTS REQUIRED. The source-and-detector system is shown in Figure 12. Recommended components are as follows:

Modulator. Type 1214-A Unit Oscillator (400 cycles and 1000 cycles)

R-F Oscillator. Type 1208-B Unit Oscillator (65-500 Mc)
Type 1209-B Unit Oscillator (250-920 Mc)
Type 1218-A Unit Oscillator (900-2000 Mc) (square-wave modulated; refer to paragraph 2.3.1)
Type 1021-AU Standard-Signal Generator (250-920 Mc) (internal modulation)
Type 1021-AV Standard-Signal Generator (50-250 Mc) (internal modulation)
Type 1021-AW Standard-Signal Generator (900-2000 Mc) (external modulation)

Pad. Type 874-GJ 10-db Pad is recommended for isolation and attenuation.

Resistor. Approximately 30 kilohms. (Omit if Type 1231-P4 Adjustable Attenuator is used.)

Amplifier. Type 1231-B Amplifier and Null Detector recommended. Other amplifiers with comparable gain and low hum level can also be used. The output circuit necessary for use with the clamping circuit is described in paragraph 2.4.3.

Clamping Circuit. Type 874-MD-P1. (Refer to paragraph 2.4.3.)

Oscilloscope. About 0.1 v/in. sensitivity (dc).

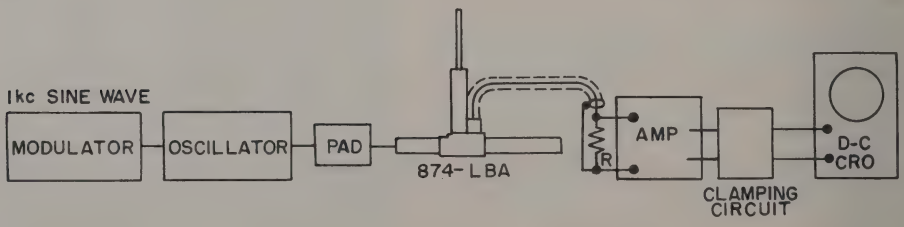

Figure 12. Source-and-Detector System for Sine-Wave Modulation.

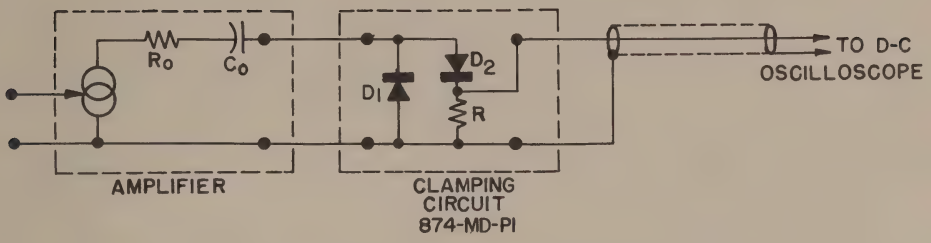

Figure 13. Clamping Circuit.

Desirable additions to the system are the Type 1231-P4 Adjustable Attenuator, which is useful for precise measurements of level, and the Type 1231-P8 or -P2 Tuned Filter, which helps to give a clean display, especially at low levels. (At high sweep speeds the tuned filter may give a horizontal displacement between the forward and reverse traces due to time delay.)

2.4.3 THE CLAMPING CIRCUIT. The Type 874-MD-P1 Clamping Circuit is used to remove the lower half of the modulated audio-frequency signal in order to provide a base line. The circuit (Figure 13) should be driven from an amplifier that has a coupling capacitor of about 1 μf and an output resistance of approximately 50 kilohms (large compared with the forward resistance of the diodes). The output circuit of the Type 1231-B Amplifier meets these requirements. If another amplifier is used, the necessary components should be added externally.

2.4.4 OPERATION. The general procedure for an oscilloscope display is given in paragraphs 3.1 and 3.2. There are, however, some considerations that are peculiar to this type of modulation. Voltage levels at various points are important for correct operation of the detector, clamping circuit, and amplifier. The r-f source should be at level low enough for good square-law response. However, if the r-f source is operated at too low a level, noise may cause a poor display.

If the clamping circuit output voltage is too low the increased forward resistance of the diodes will cause improper clamping and an uneven base line. The output voltage at a minimum point should be about 0.1 volt.

The amplifier must not clip or distort, for this would cause errors in measurement.

A suggested method of setting levels is as follows:

a. Connect the Slotted-Line output directly to the oscilloscope with the line unterminated. Set the oscillator gain to give a display whose peak-to-peak value is approximately 10 mv.

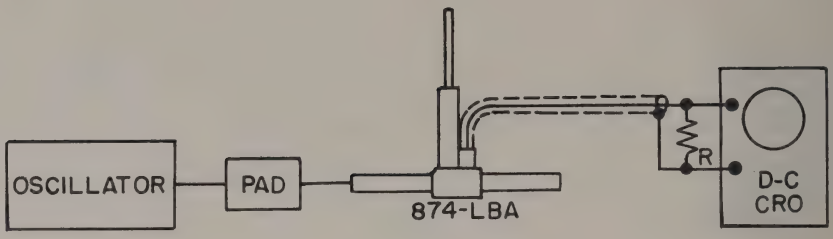

Figure 14. Source-and-Detector System with Unmodulated Source.

b. Connect the Slotted-Line output to the amplifier, and the output of the clamping circuit to the oscilloscope. Set the oscilloscope for approximately 0.2 volt per inch.

c. Adjust the amplifier gain for the desired deflection. To check the over-all characteristics, terminate the line in a known impedance (such as the Type 874-W100 100-ohm Coaxial Standard), and read the VSWR on the overlay. Adjust the various levels for the most accurate reading.

2.5 UNMODULATED SOURCE.

2.5.1 CHARACTERISTICS. The most simple display is that using an unmodulated source. No base (ground) line is displayed. The base line can be easily determined, however, by turning off the oscillator or by grounding the oscilloscope input. This is satisfactory for many applications if the oscilloscope drift is low. In applications where the VSWR is being set to a minimum, no base line is necessary. Except for the lack of a base line the operation is the same as that for a square-wave modulated source.

2.5.2 INSTRUMENTS REQUIRED. The source-and-detector system is shown in Figure 14. Recommended components are as follows:

R-F Oscillator. Type 1208-B Unit Oscillator (65-500 Mc)
Type 1209-B Unit Oscillator (250-920 Mc)
Type 1218-A Unit Oscillator (900-2000 Mc) (square-wave modulated; refer to paragraph 2.3.1)
Type 1021-AU Standard-Signal Generator (250-920 Mc)
Type 1021-AV Standard-Signal Generator (50-250 Mc)
Type 1021-AW Standard-Signal Generator (900-2000 Mc)

Pad. Type 874-GJ 10-db Pad is recommended for isolation and attenuation.

Resistor. Approximately 30 kilohms.

Oscilloscope. At least 10 mv/in. sensitivity (dc).

Section 3

PRESENTATION

3.1 SETUP PROCEDURE.

3.1.1 GENERAL. The following is the procedure for setting up an oscilloscopic display. If a meter display is desired, refer to the Operating Instructions for the Type 874-LBA Slotted Line and paragraph 1.5 of this book.

3.1.2 PROCEDURE.

a. Assemble the Motor Drive as described in paragraph 1.3.

b. Select the type of modulation desired and connect the source and detector as outlined in paragraphs 2.3, 2.4, or 2.5. Use shielded leads.

c. Attach the transparent overlay to the oscilloscope. The overlay will fit directly on the Dumont Types 304-A and 324 oscilloscopes. Mounting holes may have to be drilled for other five-inch oscilloscopes. Make sure that the horizontal lines are parallel to a horizontal trace.

d. Connect the SWEEP terminals on the Motor Drive Unit to the oscilloscope horizontal input by means of a shielded cable.

e. Turn on the source-and-detector system and set levels as described in paragraphs 2.3 and 2.4. If the source voltage level is inadequate, it may be necessary to increase the coupling to the probe of the Slotted Line. (Refer to Type 874-LBA Slotted Line Operating Instructions, paragraph 4.3.) The oscillators recommended provide an output that is far greater than that required with the probe penetration suggested in the Slotted Line Operating Instructions.

f. Tune the Type 874-D20 Stub for maximum oscilloscope deflection. (If the line is shorted or open, make sure it is not at a voltage minimum point.) Make sure to tune for the fundamental source frequency and not a harmonic. (Refer to Type 874-LBA Operating Instructions, paragraph 4.21.)

If the stub can be tuned at several positions, use the position with the shortest stub length. Clamp the stub with the clamp provided so that it will not slide in.

g. Position the microswitch brackets to provide the desired sweep distance.

h. Position the display on the oscilloscope. For measurements using the overlay, see paragraph 3.2.

NOTE

Early models of the Type 874-LBA Slotted Line contain a Type 1N21B crystal in the detector. In order to present a

display with the base (ground) line at the bottom with square-wave modulation or an unmodulated source, it is necessary to replace the crystal with a Type 1N21BR reverse crystal. (Refer to Type 874-LBA Operating Instructions, paragraph 6.1 for replacement directions.

3.2 MEASUREMENT PROCEDURE.

3.2.1 GENERAL. The oscilloscope mask provided permits a quick indication of the VSWR and of the position of the minima, from which the impedance of the termination can be determined. The display should be similar to those shown in Figures 9 and 11. Section 3.5 lists probable causes of difficulties in obtaining a satisfactory display.

3.2.2 VSWR MEASUREMENT. Low values of VSWR (up to about 4) can be read directly by means of the following procedure. (For higher VSWR measurements refer to the Type 874-LBA Slotted Line Operating Instructions.)

a. Adjust the vertical centering control so that the base line coincides with the bottom line (∞) of the mask.
b. Adjust the amplitude so that the voltage maxima fall on the top line (VSWR = 1) of the mask.
c. The position of the minima as read on the vertical scale of the mask indicates the VSWR.

The accuracy obtainable depends upon the type of modulation and the VSWR. Sine-wave modulation should result in high accuracy since it is possible to work at low r-f levels. With a sensitive d-c oscilloscope, square-wave modulation (or no modulation) should give satisfactory results. With a VSWR of 2, the accuracy should approach five percent if the oscilloscope sensitivity is 10 mv/in. Low VSWR values will be more accurate than larger values due to the shape of the scale.

3.2.3 MEASUREMENT OF IMPEDANCE AND COMPLEX REFLECTOR COEFFICIENT. If the unknown is known to be resistive (so that $|\Gamma| = \Gamma$), the resistance can be calculated directly from the VSWR.

$$Z_x = 50 \text{ ohms} \times \text{VSWR}, \text{ if } Z_x > 50 \text{ ohms}$$

$$Z_x = \frac{50 \text{ ohms}}{\text{VSWR}} \quad \text{if } Z_x < 50 \text{ ohms}$$

However, if the unknown is complex, the horizontal position of the pattern must also be determined. The procedure is as follows:

a. Short-circuit the line with a Type 874-WN or WN3 Short-Circuit Termination, and set the horizontal gain and centering controls so that

the minima coincide with the 0, 0.5, and 1.0 positions of the horizontal scale marked WAVELENGTHS. (Note that there are two cycles per wavelength; refer to paragraph 3.3.)

b. Place the unknown on the line and note the shift of the minima in wavelengths on the horizontal scale. Note also the direction of this shift, whether it is toward the generator or toward the detector (left or right on the oscilloscope). For direct indication of this shift in minima it is imperative that the electrical distance to the short circuit and to the unknown be the same. The Type 874-M Component Mount places the unknown at the same electrical distance as the Type 874-WN-3 3-cm Short-Circuit Termination. The Type 874-WN Short-Circuit Termination produces a short circuit at the front face of the polystyrene insulator in the Type 874 Connector. (Refer to Type 874-LBA Operating Instructions, paragraph 4.12.)

c. Use a Smith Chart to determine impedance. The distance from the center (radius) is a function of the VSWR, the angle rotated is that of the minima. (Refer to the Type 874-LBA Slotted Line Operating Instructions, paragraph 4.7, for details and examples of this measurement and construction.)

The shift of the minima is the angle of the reflection coefficient Γ. The angle of Γ in degrees is (fraction of a wavelength shifted) x 360° if the pattern is set up to give two visual cycles per wavelength on the overlay. The reflection coefficient has a positive imaginary part (inductive load) if the pattern is shifted toward the generator, and a negative imaginary part (capacitive load) if the pattern is shifted toward the detector.

The magnitude of Γ is:

$$|\Gamma| = \frac{\text{VSWR} - 1}{\text{VSWR} + 1}$$

3.3 EXPRESSION FOR THE STANDING-WAVE PATTERN. If the line is assumed lossless and is terminated in an impedance Z_x, the voltage standing-wave pattern can be expressed as:

$$\frac{|E|}{|E_{in}|} = \sqrt{1 + |\Gamma|^2 + 2|\Gamma| \cos(2\Theta - \phi)}$$

where:

$|E|$ = magnitude of r-f voltage along the line
$|E_{in}|$ = magnitude of input voltage to the line
Θ = electrical distance to the load
Γ = reflection coefficient

$$\Gamma = \frac{Z_x - Z_o}{Z_x + Z_o} = A + jB$$

where:

Z_x = terminating impedance
Z_o = line impedance (50 ohms)
$|\Gamma|$ = magnitude of the reflection coefficient = $\sqrt{A^2 + B^2}$
ϕ = angle of the reflection coefficient = $\tan^{-1} B/A$

The voltage standing-wave ratio (VSWR) is the ratio of maximum to minimum voltage.

$$\text{VSWR} = \frac{\sqrt{1 + 2|\Gamma| + |\Gamma|^2}}{\sqrt{1 - 2|\Gamma| + |\Gamma|^2}} = \frac{1 + |\Gamma|}{1 - |\Gamma|}$$

The detector, however, is usually operated in its square-law region (refer to paragraph 3.4) so that the d-c output is proportional to the square of the r-f voltage in the line.

$$\frac{E\ dc}{E\ in} \sim 1 + |\Gamma|^2 + |\Gamma| \cos(2\Theta - \phi)$$

Note that the above includes a d-c term and a sinusoidal term of half wavelength. The VSWR is now the square root of the ratio of maximum to minimum voltage. The oscilloscope mask is calibrated to make the VSWR direct-reading if the detector is square law. Note how the pattern is shifted by an angle ϕ if Γ is complex.

3.4 DETECTOR CHARACTERISTICS. The Slotted-Line crystal should be operated at low voltage levels in order that the detector crystal will operate as a good square-law device, permitting VSWR to be determined from the calibration of the oscilloscope overlay. The detector should be terminated in a resistor of approximately 30 kilohms when the detector is connected to the oscilloscope (square-wave or no modulation). With some crystals, better square-law response may be possible with a terminating resistor of a slightly different value. It is desirable to check the response with a known line termination such as the Type 874-W100 100-ohm Coaxial Standard, and to vary the detector terminating resistor to obtain the correct VSWR indication. With sine-wave modulation, the a-c amplifier permits operation at lower levels so that the value of the terminating resistor is not as important.

A typical plot of the detector characteristics is given in Figure 15. The detector could be operated with any characteristic as long as the characteristic is known. It should be possible to operate the crystal as

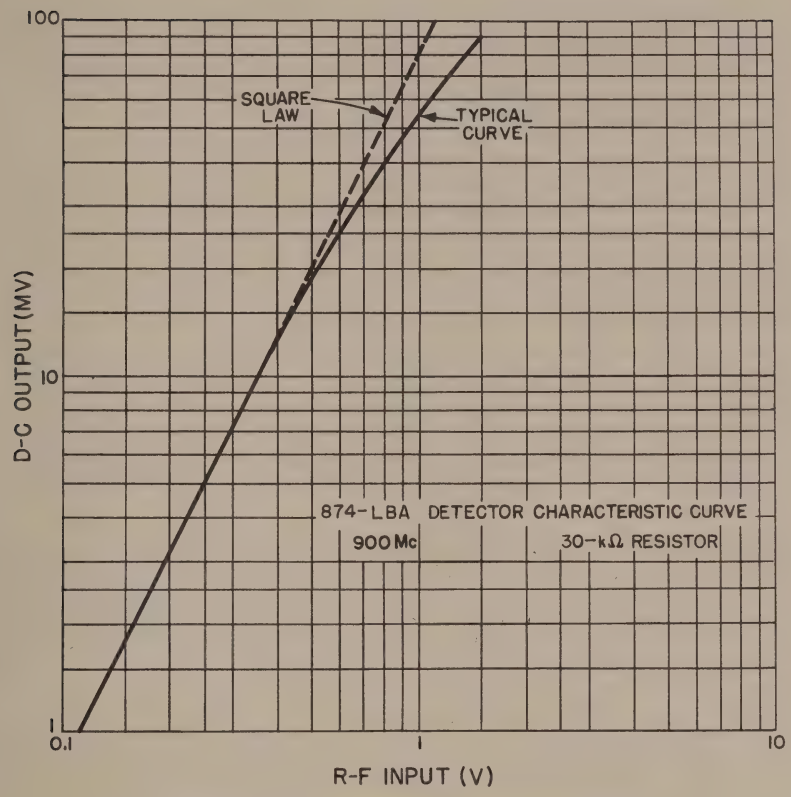

Figure 15. Detector Characteristics.

a linear detector if enough input power is available. The voltage must be high enough so that at a voltage minimum the level is well above one volt. A response approximating linear operation at low VSWR's is possible with the Types 1209-B and 1218-A Unit Oscillators. However, VSWR can be more accurately determined by use of the detector in its square-law region.

3.5 DISPLAY DIFFICULTIES.

3.5.1 GENERAL. The following paragraphs describe several difficulties that may cause poor display. Refer also to paragraph 2.3, 2.4, or 2.5 (depending on type of display).

3.5.2 IRREGULAR VERTICAL NOISE. Minor irregularities caused by vibration are unavoidable at high speeds. However, they can be reduced by lubrication of the Slotted Line (refer to paragraph 4.3) and by tightening up of the stub clamps. Check also to see that the pulley and belt drive is running smoothly and that all four feet of the line are resting firmly on the bench.

Vertical noise can also be caused by pickup. Make sure that leads are well shielded, and keep the motor lead away from the oscilloscope or amplifier. When working at very low levels (sine-wave modulation), noise from the source or the amplifier can be reduced by a tuned filter. (Refer to paragraph 2.4.2.)

3.5.3 VERTICAL SPIKE ON THE END OF THE TRACE. A small spike is caused by the reversing jolt, which rocks the carriage and changes the probe coupling. A large spike could be caused by failure of one of the capacitors across the relay contacts.

3.5.4 VERTICAL DISPLACEMENT BETWEEN TRACES. First make sure that the tuning stub is clamped securely. If the stub is secure, and if the vertical position of the trace depends upon the direction of travel, the probe carriage may not be righting itself after the reversing jolt. Tighten the springs bearing on the nylon plugs in the carriage. (Refer to Type 874-LBA Operating Instructions, paragraph 6.5.) This should cause the carriage to return to the same position.

3.5.5 HUM ON TRACE AND BASE LINE. Hum can be caused by ground currents in the oscilloscope. To check this, remove the leads to the oscilloscope and connect the vertical input to the horizontal ground terminal. If hum appears, ground the horizontal sweep at the vertical ground terminal, leaving the horizontal ground terminal open.

3.5.6 HORIZONTAL NOISE. Horizontal noise is due to poor contact between the potentiometer and its contact element. If increasing the pressure does not clear up the noise, it may be necessary to clean the potentiometer with crocus cloth.

3.5.7 HORIZONTAL DISPLACEMENT BETWEEN TRACES. Horizontal displacement resulting in a difference in horizontal position between the forward and reverse trace may be due to a short between the potentiometer supply voltage and ground. Make an ohmmeter check at the potentiometer lead plug to make sure the braided shield is not shorted to ground.

The display should be displaced when the microswitches are held closed, because of the regulation in the transformer. However, the momentary closing during normal use should have no effect if the potentiometer supply filter is operating correctly.

With sine-wave modulation a small horizontal displacement is possible at high speeds due to time delay if a sharp filter is used.

3.5.8 UNEVEN HEIGHT OF MAXIMA. Irregularities in probe coupling along the line will result in uneven height of the maxima. This should be very small. (Refer to Type 874-LBA Operating Instructions, paragraph 5.2.) Uneven height caused by losses in the line should be negligible.

Section 4

SERVICE AND MAINTENANCE

4.1 GENERAL. The schematic wiring diagram (Figure 18) and interior views (Figures 16 and 17), along with the circuit descriptions and diagrams of paragraph 1.2, should enable the user to locate and correct ordinary difficulties resulting from normal use. Refer to the Type 874-LBA Slotted Line Operating Instructions for maintenance of the Slotted Line itself. Difficulties resulting in poor display are discussed in paragraph 3.5.

4.2 FACTORY SERVICE. Major service problems should be referred to our Service Department, which will cooperate as much as possible by furnishing information and instructions as well as by supplying any replacement parts needed.

When notifying our Service Department of any difficulties in operation or service, specify the serial and type numbers of the instrument. (The serial number is stamped on the inside of the cabinet.) Also give a complete report of trouble encountered and steps taken to eliminate the trouble.

Before returning any instrument or parts for repair, please write to our Service Department, requesting a Returned Material Tag, which includes shipping instructions. Use of this tag will insure proper handling and identification. The purchase order covering repairs to equipment returned should also be forwarded to avoid unnecessary delay.

4.3 LUBRICATION. When the Slotted Line is automatically swept, it is necessary to keep it well lubricated to prevent excessive wear and to insure a satisfactory display. To lubricate, put oil in the two small holes on the top and at each end of the probe carriage. The front supporting rod of the line should also be well oiled where it rubs the bottom of the probe carriage. Use a light machine oil.

4.4 MICROSWITCH REPLACEMENT. A spare microswitch is provided, since this component is susceptible to mechanical failure, especially if used incorrectly. If the microswitch is depressed too far, the spring arm will be bent enough to cause eventual failure. When replacing the microswitch element, mount it so that the bottom of the roller on the arm is level with the top of the bracket.

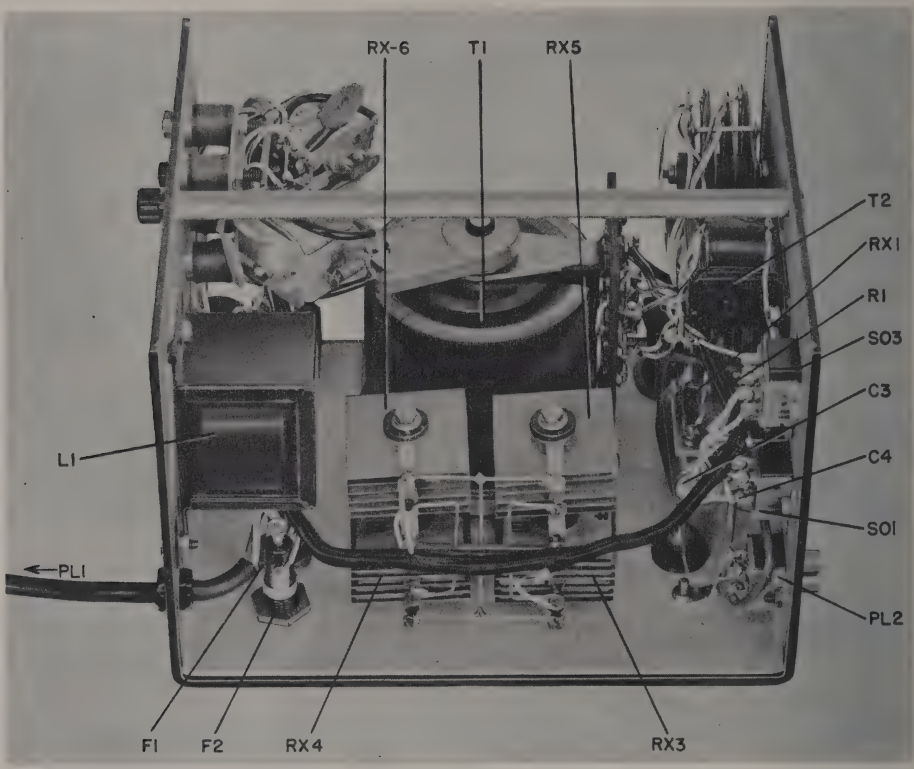

Figure 16. Interior View of Motor Speed Control Unit.

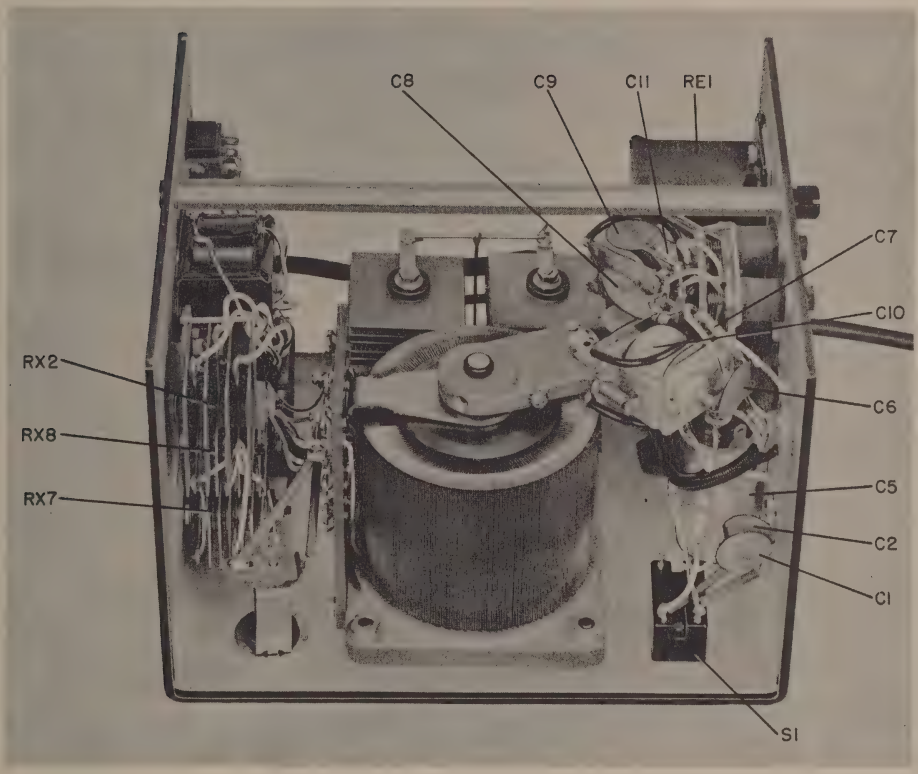

Figure 17. Interior View of Motor Speed Control Unit.

Section 5

PARTS LIST

		GR No.
C1	CAPACITOR, Ceramic, 0.01 μf +100%-0%, 500 dcwv	COC-63
C2	CAPACITOR, Ceramic, 0.01 μf +100%-0%, 500 dcwv	COC-63
C3	CAPACITOR, Electrolytic, 100 μf +100%-10%, 25 dcwv	COE-35
C4	CAPACITOR, Electrolytic, 100 μf +100%-10%, 25 dcwv	COE-35
C5A	CAPACITOR, Electrolytic, 100 μf +100%-10%, 25 dcwv	COE-15
C5B	CAPACITOR, Electrolytic, 100 μf +100%-10%, 25 dcwv	
C6	CAPACITOR, Ceramic, 0.01 μf +100%-0%, 500 dcwv	COC-63
C7	CAPACITOR, Ceramic, 0.01 μf +100%-0%, 500 dcwv	COC-63
C8	CAPACITOR, Ceramic, 0.01 μf +100%-0%, 500 dcwv	COC-63
C9	CAPACITOR, Ceramic, 0.01 μf +100%-0%, 500 dcwv	COC-63
C10	CAPACITOR, Ceramic, 0.01 μf +100%-0%, 500 dcwv	COC-63
C11	CAPACITOR, Ceramic, 0.01 μf +100%-0%, 500 dcwv	COC-63
F1	FUSE, 1 amp, Slo-Blo (for 115 v)	FUF-1
F2	FUSE, 1 amp, Slo-Blo (for 115 v)	FUF-1
J1	BINDING POST	BP-5
J2	BINDING POST	BP-10, 11/16
L1	CHOKE	745-409
MO1	MOTOR	874-MD-41
P1	PILOT LIGHT, 6.3 v	2LAP-939
PL1	PLUG	CAP-1-2
PL2	PLUG	CDMP-1264-4
PL3	PLUG	CDMP-1275-4
PL4	PLUG	CDMP-1275-6
R1	RESISTOR, Fixed composition, 10 k ±10%, 1/2 w	REC-20BF
R2	RESISTOR, Variable, 7 k ±20%	874-MD-200
RE1	RELAY	874-MD-40
RX1	RECTIFIER, Crystal	1N51
RX2	RECTIFIER	2RE-24
RX3	RECTIFIER	2RE-6
RX4	RECTIFIER	2RE-6
RX5	RECTIFIER	2RE-6
RX6	RECTIFIER	2RE-6
RX7	RECTIFIER	2RE-5
RX8	RECTIFIER	2RE-5
S1	SWITCH, dpst	SWT-333, NP
S2	SWITCH	874-MD-42
S3	SWITCH	874-MD-42
SO1	SOCKET	CDMS-1262-4
SO2	SOCKET	CDMS-1-4
SO3	SOCKET	CDMS-1262-6
T1	VARIAC	V-2-400
T2	TRANSFORMER	746-427

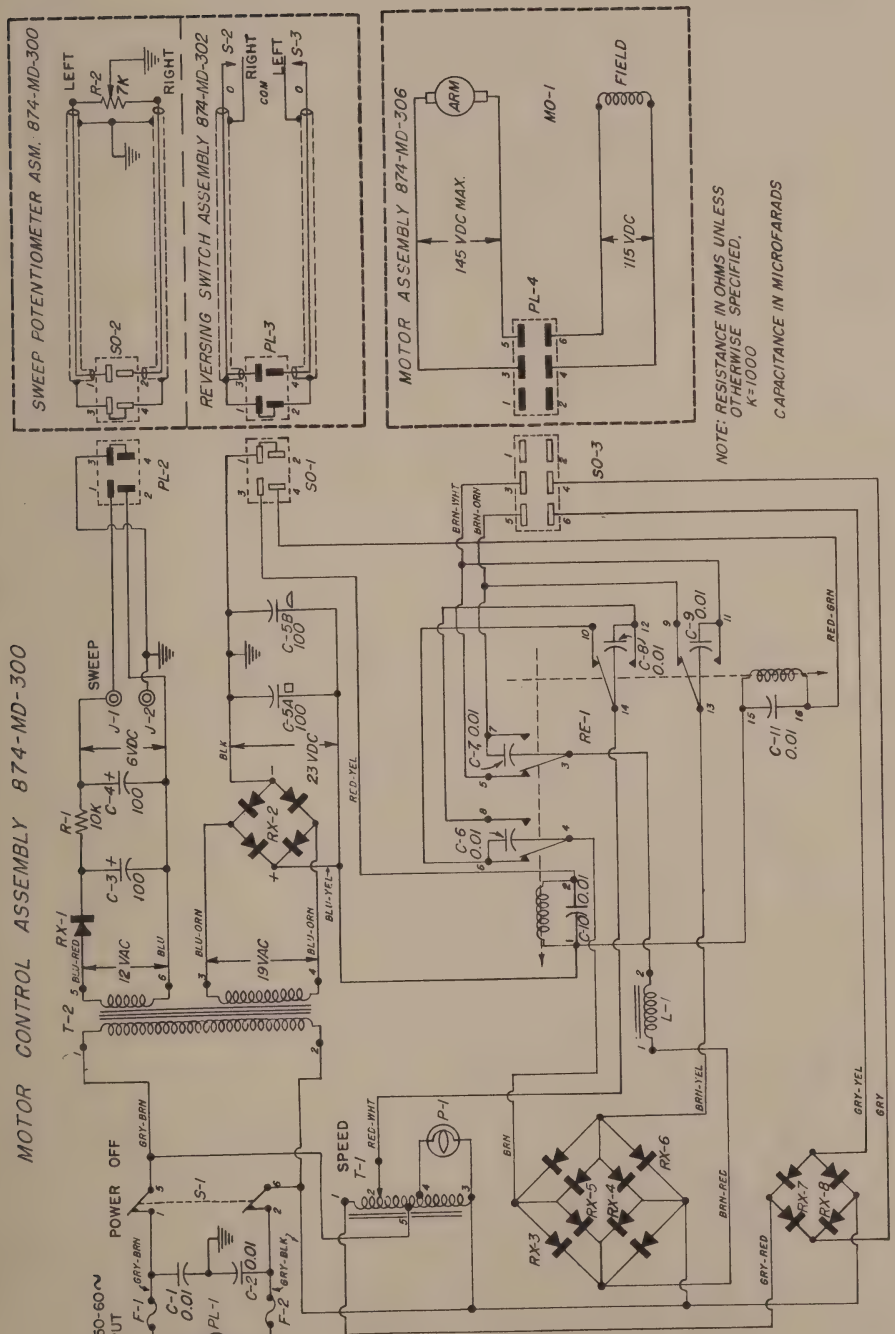

Figure 18. Schematic Wiring Diagram

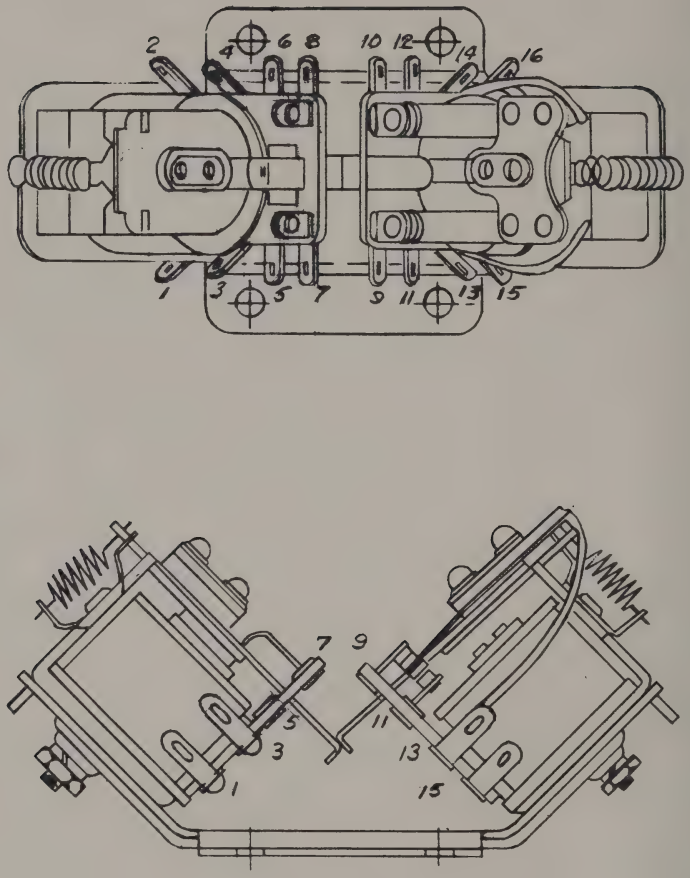

Figure 19. Latching Relay